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# Position Computation Without Elevation Information for Computed Centerline Operations

Barry R. Billman  
Christopher J. Wolf

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## EXECUTIVE SUMMARY

This report presents the results of an analytical investigation, undertaken by the Federal Aviation Administration (FAA) Technical Center, into the errors induced in Microwave Landing System (MLS) Area Navigation (RNAV) position computation by an algorithm that does not use elevation information. This investigation was to provide information to the International Civil Aviation Organization's (ICAO) All Weather Operations Panel (AWOP). These results were presented to the ICAO AWOP Working Group B in Canberra, Australia, between May 22 and June 2, 1989.

Computed centerline approaches can be divided into two subclasses: approaches to an instrument runway with an offset azimuth configuration, and approaches to a runway parallel to the primary instrumented runway. The use of lateral position computation algorithms that do not require an input elevation parameter have been proposed for situations where a full three-dimensional algorithm would be difficult in terms of memory requirements or computational power. An analytical investigation of the impact of siting configurations on the accuracy of this type of algorithm was necessary. The crosstrack and along-track errors induced at several locations on both 3° and 6° approaches are presented. The locations of interest were: Category I and Category II minima (200-foot decision height (DH) and 100-foot DH, respectively); approach reference datum (ARD), 50 feet above ground level (AGL) on the approach glidepath for Category III; and at 5 nautical miles (nmi) from the MLS datum point on the approach glidepath.

Results from this analytical investigation indicate that for azimuth station offsets greater than 800 feet from runway centerline, elevation information should be used in MLS RNAV position determination.

## INTRODUCTION

### PURPOSE.

The purpose of this report is to document the results of an analytical investigation into the errors induced in Microwave Landing System (MLS) Area Navigation (RNAV) position computation by an algorithm that does not use elevation information. The investigation was performed for computed centerline operations with offset ground station siting configuration. This investigation was undertaken by the Federal Aviation Administration (FAA) Technical Center to provide information to the International Civil Aviation Organization's (ICAO's) All Weather Operations Panel (AWOP). This report, in the form of an information paper, was presented at the Fourth meeting of ICAO AWOP Working Group B in Canberra, Australia, between May 22 and June 2, 1989.

### BACKGROUND.

Computed centerline approaches can be divided into two subclasses: approaches to an instrument runway with an offset azimuth configuration, and approaches to a runway parallel to the primary instrumented runway. The use of lateral position computation algorithms that do not require an input elevation parameter have been proposed for situations where a full three-dimensional algorithm would be difficult in terms of memory requirements or computational power. An investigation of the impact of siting configurations on the accuracy of this type of algorithm was necessary.

## DISCUSSION

The case 9 algorithm from the Radio Technical Commission for Aeronautics (RTCA), document DO-198, was modified so only azimuth angle and precision distance measuring equipment (DME/P) range data were used to determine along-track and crosstrack position. MLS ground station siting configurations were analytically varied such that the azimuth offset from runway centerline ranged from 0 to 2000 feet in 50-foot increments. The azimuth to elevation station separation distance ranged from 6000 to 10000 feet in 1000-foot increments. The azimuth and DME/P stations were assumed to be collocated. All ground station data were considered to be error free. Crosstrack and along-track errors, induced by the modified algorithm, were determined at Categories I, II, and III approach reference locations (200-foot decision height (DH) for Category I, 100-foot DH for Category II, and the 50-foot approach reference datum (ARD) for Category III) on both 3° and 6° glidepaths. These errors were also determined at a slant range of 5 nautical miles (nmi) from the MLS datum point for both 3° and 6° glidepaths. The along-track and crosstrack errors are the difference between the theoretical intended position and where the modified case 9 algorithm, using no elevation information, determined the aircraft's position to be.

## RESULTS

Figure 1 presents the magnitude of the crosstrack error versus azimuth station offset for each azimuth (AZ) to elevation (EL) separation distance at the Category I minima (200 feet) on a 3° approach. Figure 2 presents the data at the Category II minima (100 feet) on a 3° approach; figure 3 presents the data at ARD (50 feet) on a 3° approach for Category III; and figure 4 presents the data for a point 5 nmi from the MLS datum point on a 3° approach.

Figure 5 presents the magnitude of the along-track error versus azimuth station offset for each AZ to EL separation distance at the Category I minima on a 3° approach. Figure 6 presents the data at the Category II minima on a 3° approach; figure 7 presents the data at ARD for Category III on a 3° approach; and figure 8 presents the data for at a point 5 nmi from the MLS datum point on a 3° approach.

Figure 9 presents the magnitude of the crosstrack error versus azimuth station offset for each AZ to EL separation distance at the Category I minima on a 6° approach. Figure 10 presents the data at the Category II minima on a 6° approach; figure 11 presents the data at ARD for Category III on a 6° approach; and figure 12 presents the data for at a point 5 nmi from the MLS datum point on a 6° approach.

Figure 13 presents the magnitude of the along-track error versus azimuth station offset for each AZ to EL separation distance at the Category I minima on a 6° approach. Figure 14 presents the data at the Category II point on a 6° approach; figure 15 presents the data at ARD for Category III on a 6° approach; and figure 16 presents the data for at a point 5 nmi from the MLS datum point on a 6° approach.

## CONCLUSIONS

Lateral position computation without the use of elevation information is possible for typical computed centerline operations to the primary instrumented runway. As the azimuth station offset becomes larger, the error induced also becomes larger. Additionally, as the azimuth (AZ) to elevation (EL) distance becomes smaller, the induced error becomes larger still.

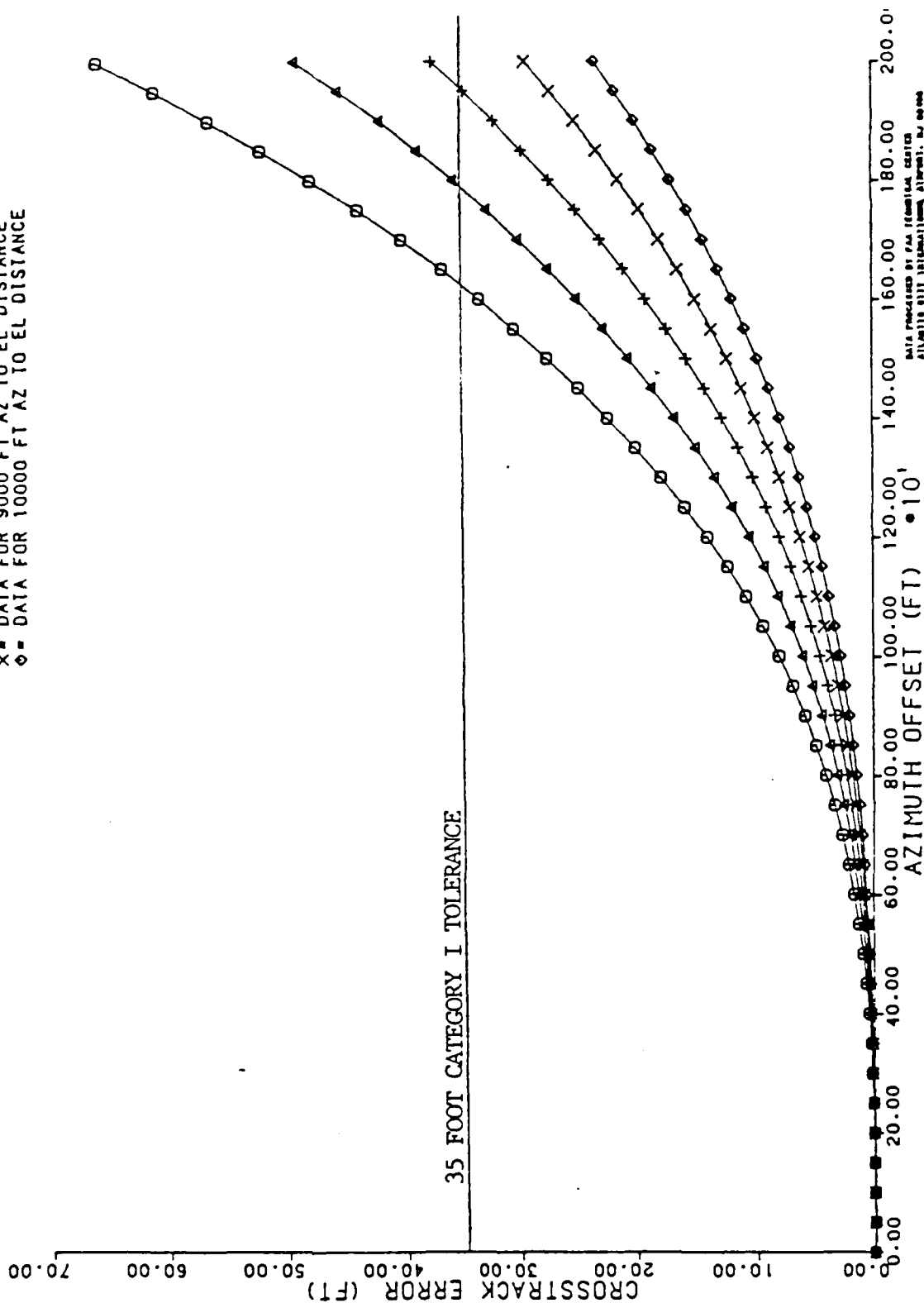
In typical siting configurations where the AZ offset is less than 800 feet, the induced error is small enough that it can be operationally ignored. Even at distances of 5 nautical miles (nmi) the errors for smaller AZ offsets are such that they pose no real problem. For the larger AZ offsets, operational consideration would be required before accepting these siting configurations.

For parallel runway situations, the lateral position error induced by the lack of elevation information consumes a significant portion of the lateral error budget at the Category I and Category II decision height (DH) windows. For this type of computed centerline approach, operational consideration of induced lateral error would be necessary. These conclusions are valid for both the 3° and 6° cases as tested, and also apply for other approach elevation angles.



ERRORS FROM 2D POSITION COMPUTATION  
APPROACH ANGLE: 3 CATEGORY I

- DATA FOR 6000 FT AZ TO EL DISTANCE
- △ DATA FOR 7000 FT AZ TO EL DISTANCE
- + DATA FOR 8000 FT AZ TO EL DISTANCE
- x DATA FOR 9000 FT AZ TO EL DISTANCE
- ◇ DATA FOR 10000 FT AZ TO EL DISTANCE



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ATWENTH 0117 101000000 010000 010000

FIGURE 1. CROSSTRACK ERROR INDUCED AT 3 DEGREE APPROACH  
CATEGORY I MINIMA

ERRORS FROM 2D POSITION COMPUTATION  
APPROACH ANGLE 3 CATEGORY II

- DATA FOR 6000 FT AZ TO EL DISTANCE
- △- DATA FOR 7000 FT AZ TO EL DISTANCE
- + - DATA FOR 8000 FT AZ TO EL DISTANCE
- x- DATA FOR 9000 FT AZ TO EL DISTANCE
- ◇- DATA FOR 10000 FT AZ TO EL DISTANCE

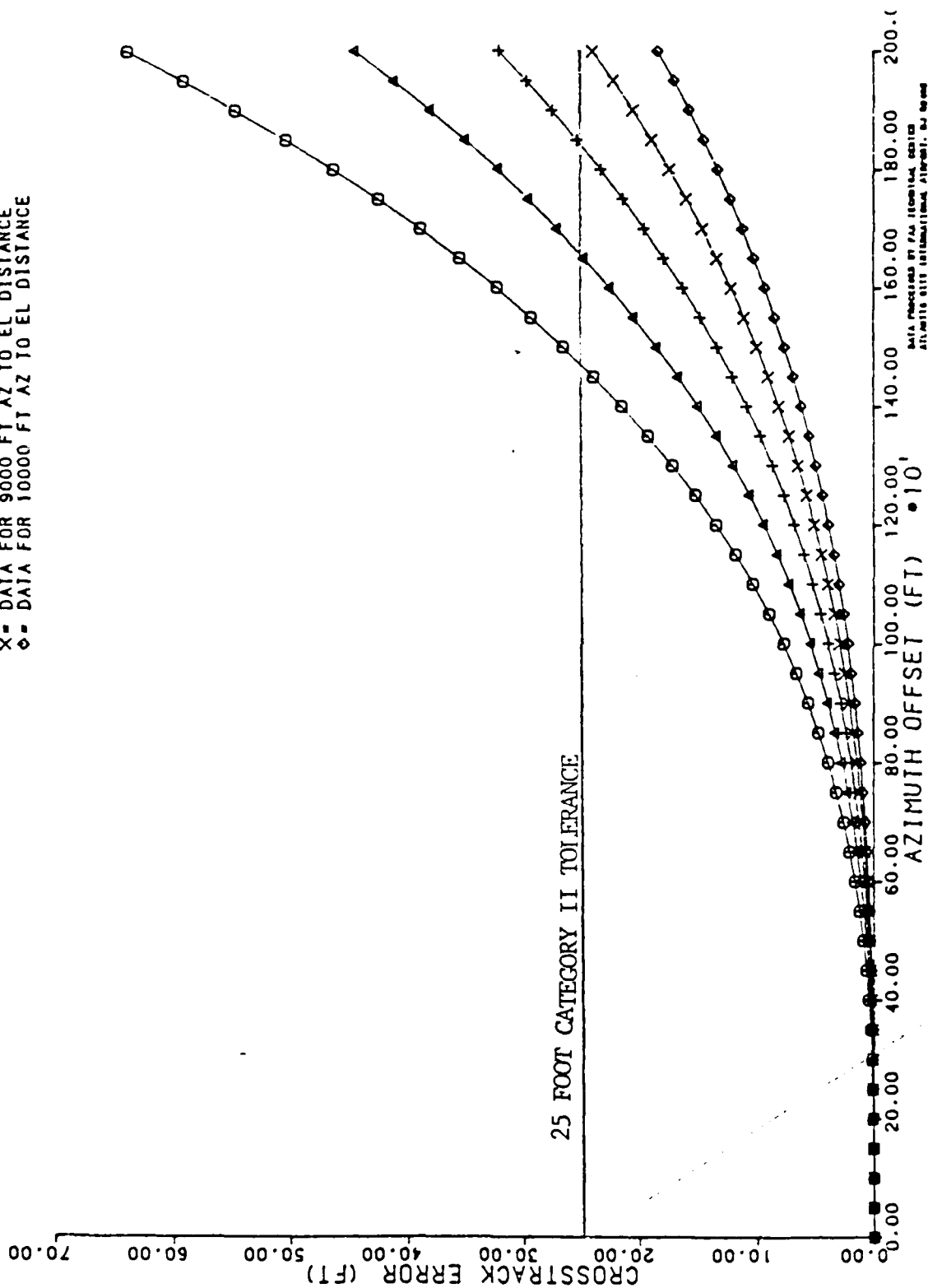
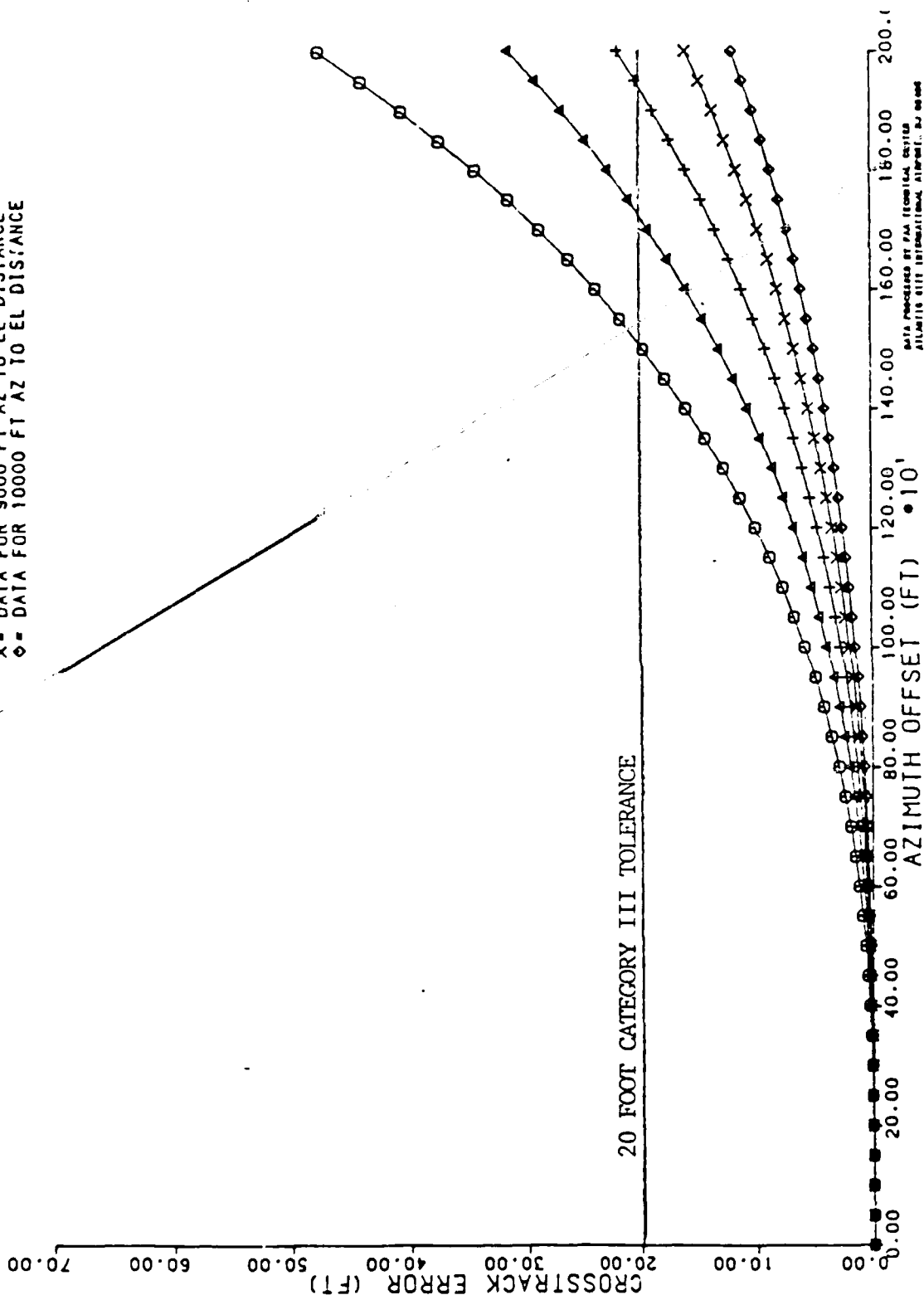


FIGURE 2. CROSSTRACK ERROR INDUCED AT 3 DEGREE APPROACH  
CATEGORY II MINIMA

ERRORS FROM 2D POSITION COMPUTATION  
APPROACH ANGLE, 3 CATEGORY III

- DATA FOR 6000 FT AZ TO EL DISTANCE
- △ DATA FOR 7000 FT AZ TO EL DISTANCE
- + DATA FOR 8000 FT AZ TO EL DISTANCE
- x DATA FOR 9000 FT AZ TO EL DISTANCE
- ◇ DATA FOR 10000 FT AZ TO EL DISTANCE



DATA PROVIDED BY FAA TECHNICAL CENTER  
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FIGURE 3. CROSSTRACK ERROR INDUCED AT 3 DEGREE APPROACH  
ARD FOR CATEGORY III

ERRORS FROM 2D POSITION COMPUTATION  
APPROACH ANGLE: 3° 5' NMI SLANT RANGE

○- DATA FOR 6000 FT AZ TO EL DISTANCE  
△- DATA FOR 7000 FT AZ TO EL DISTANCE  
+- DATA FOR 8000 FT AZ TO EL DISTANCE  
X- DATA FOR 9000 FT AZ TO EL DISTANCE  
◇- DATA FOR 10000 FT AZ TO EL DISTANCE

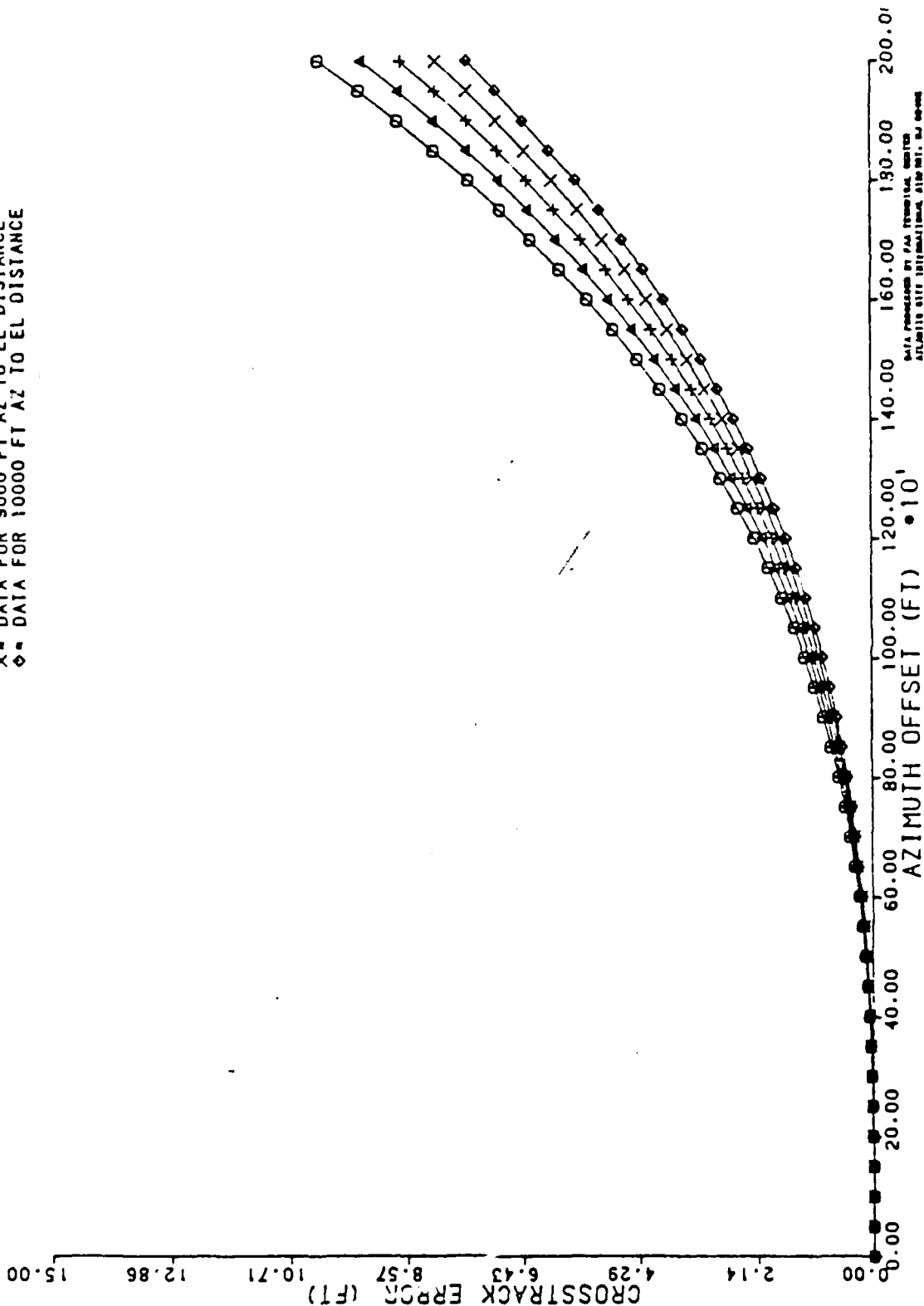


FIGURE 4. CROSTRACK ERROR INDUCED AT 5 NMI FROM MLS  
DATUM ON A 3 DEGREE APPROACH

ERRORS FROM 2D POSITION COMPUTATION  
APPROACH ANGLE: 3 CATEGORY 1

○- DATA FOR 6000 FT AZ TO EL DISTANCE  
△- DATA FOR 7000 FT AZ TO EL DISTANCE  
+ - DATA FOR 8000 FT AZ TO EL DISTANCE  
x- DATA FOR 9000 FT AZ TO EL DISTANCE  
◇- DATA FOR 10000 FT AZ TO EL DISTANCE

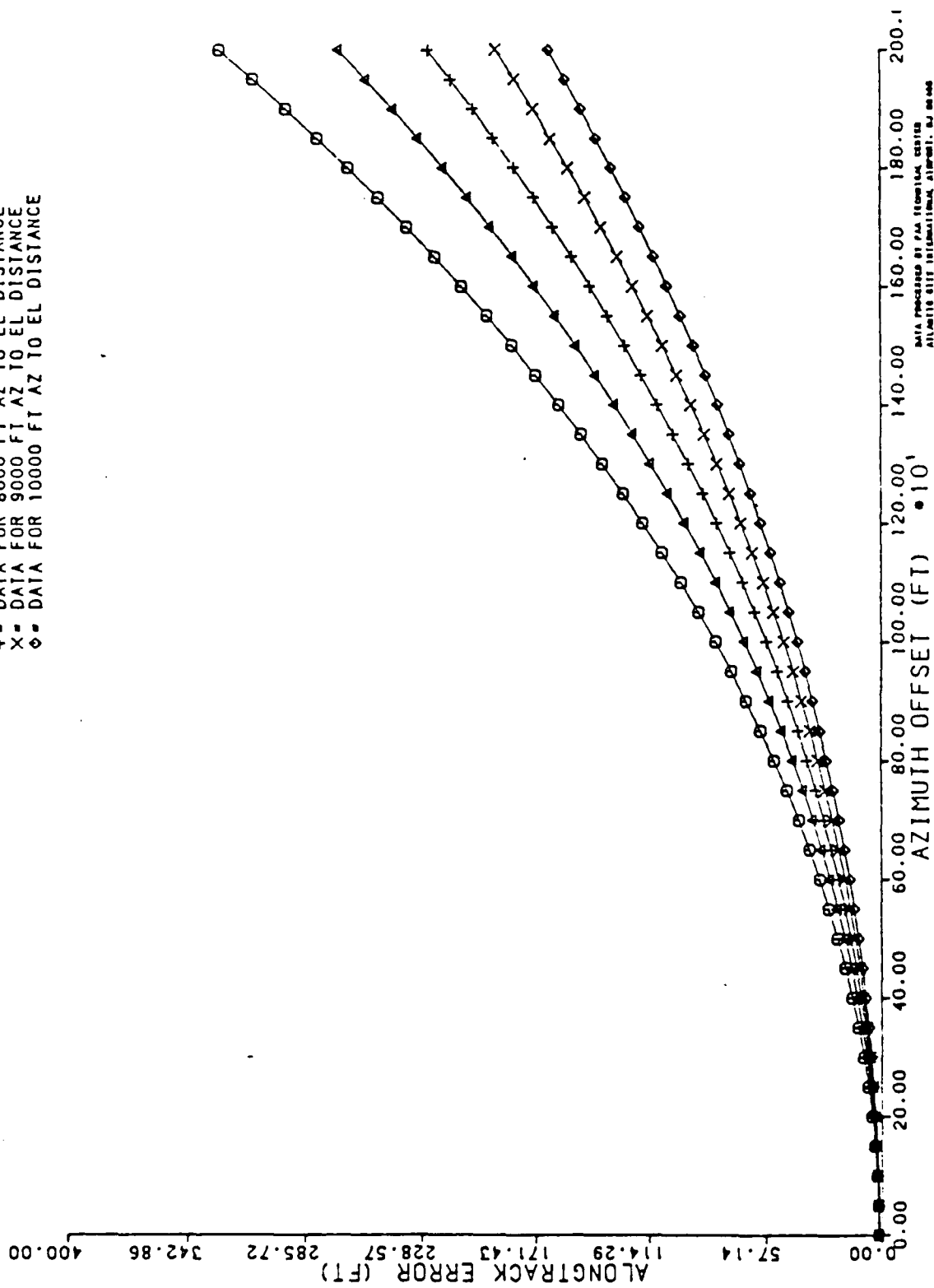


FIGURE 5. ALONG-TRACK ERROR INDUCED AT 3 DEGREE APPROACH  
CATEGORY 1 MINIMA

ERRORS FROM 2D POSITION COMPUTATION  
APPROACH ANGLE: 3 CATEGORY II

O= DATA FOR 6000 FT AZ TO EL DISTANCE  
A= DATA FOR 7000 FT AZ TO EL DISTANCE  
+ = DATA FOR 8000 FT AZ TO EL DISTANCE  
X= DATA FOR 9000 FT AZ TO EL DISTANCE  
◇= DATA FOR 10000 FT AZ TO EL DISTANCE

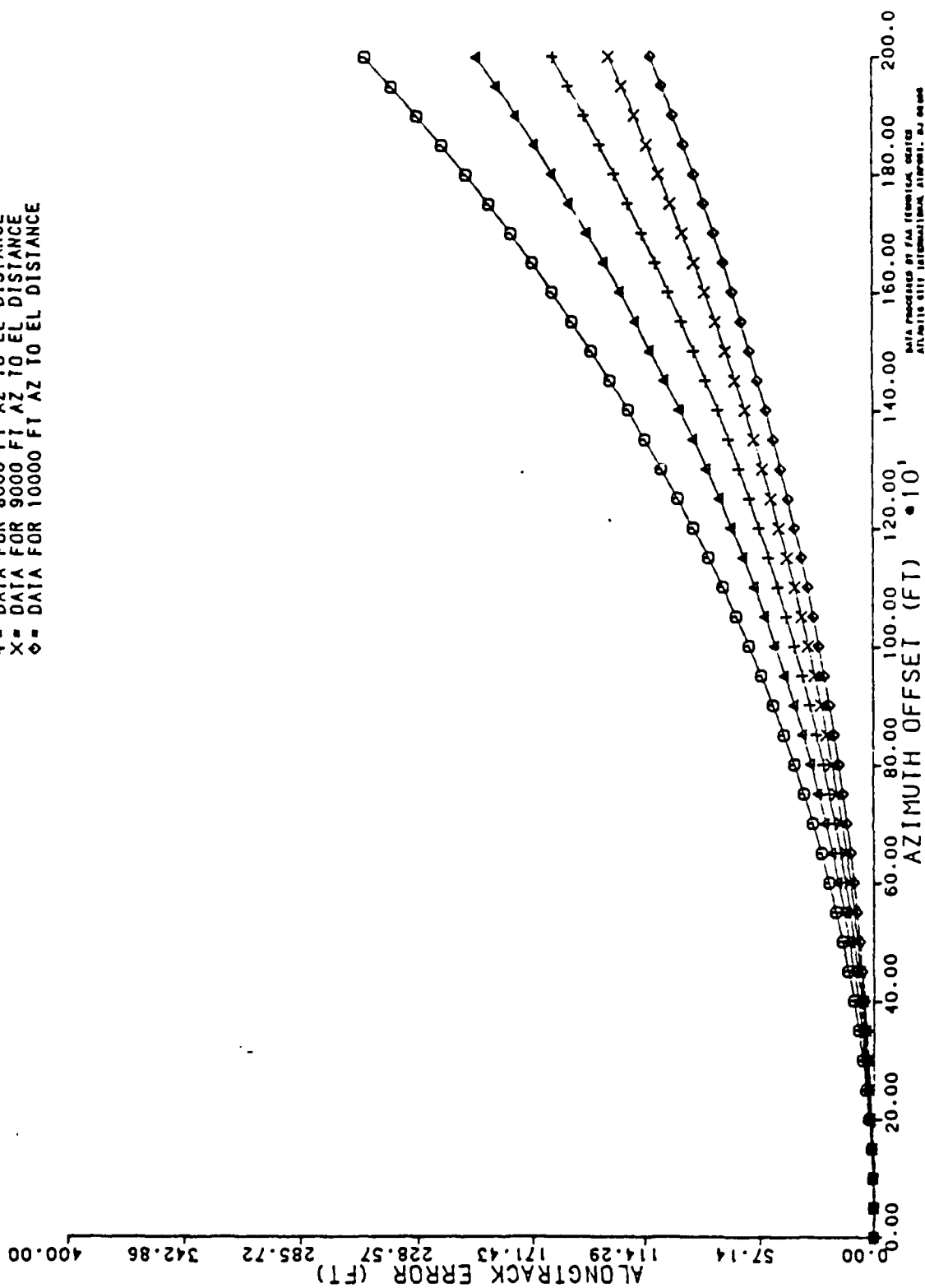


FIGURE 6. ALONG-TRACK ERROR INDUCED AT 3 DEGREE APPROACH  
CATEGORY II MINIMA

ERRORS FROM 2D POSITION COMPUTATION  
APPROACH ANGLE, 3 CATEGORY III

O- DATA FOR 6000 FT AZ TO EL DISTANCE  
A- DATA FOR 7000 FT AZ TO EL DISTANCE  
+ DATA FOR 8000 FT AZ TO EL DISTANCE  
X- DATA FOR 9000 FT AZ TO EL DISTANCE  
◇- DATA FOR 10000 FT AZ TO EL DISTANCE

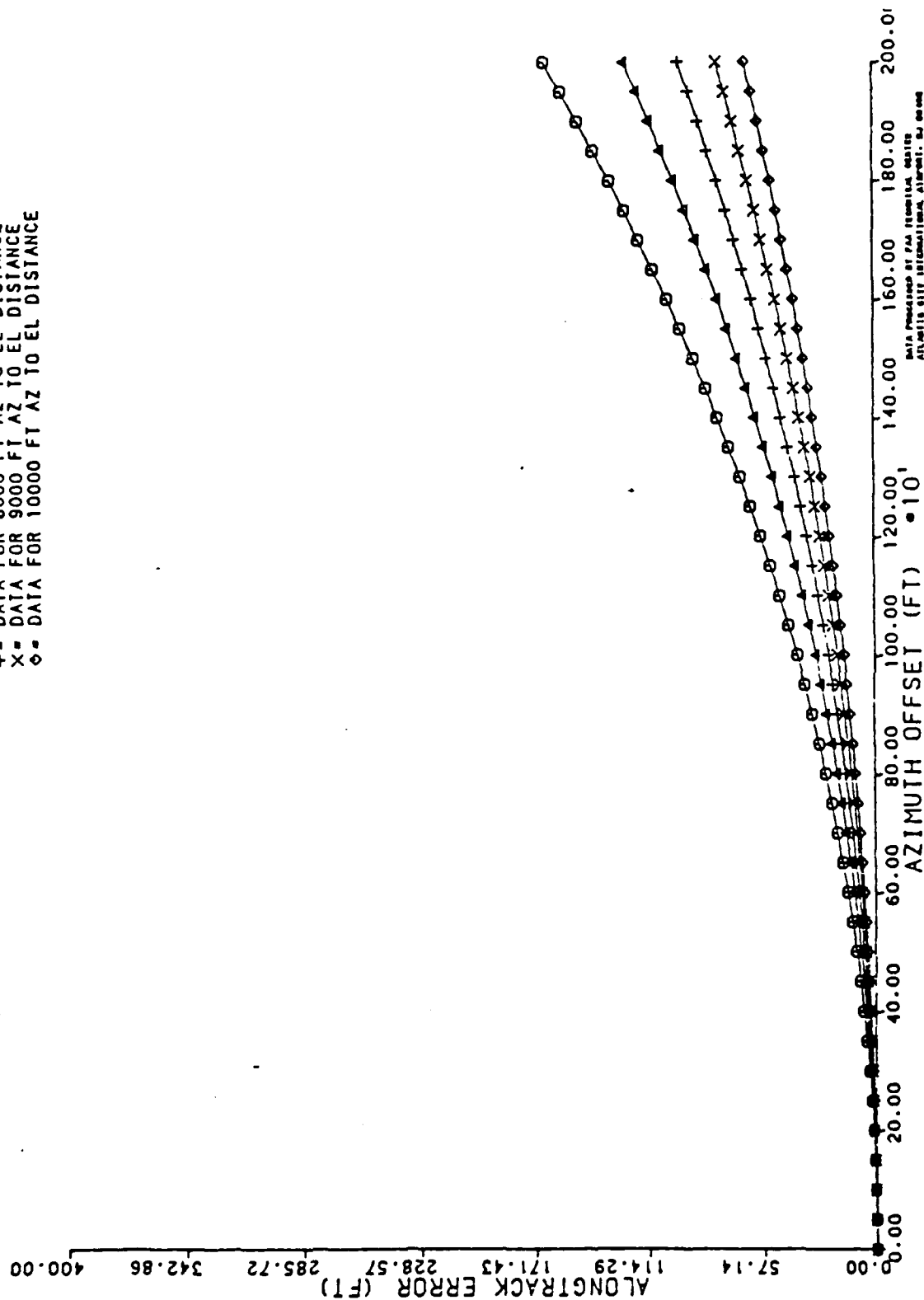
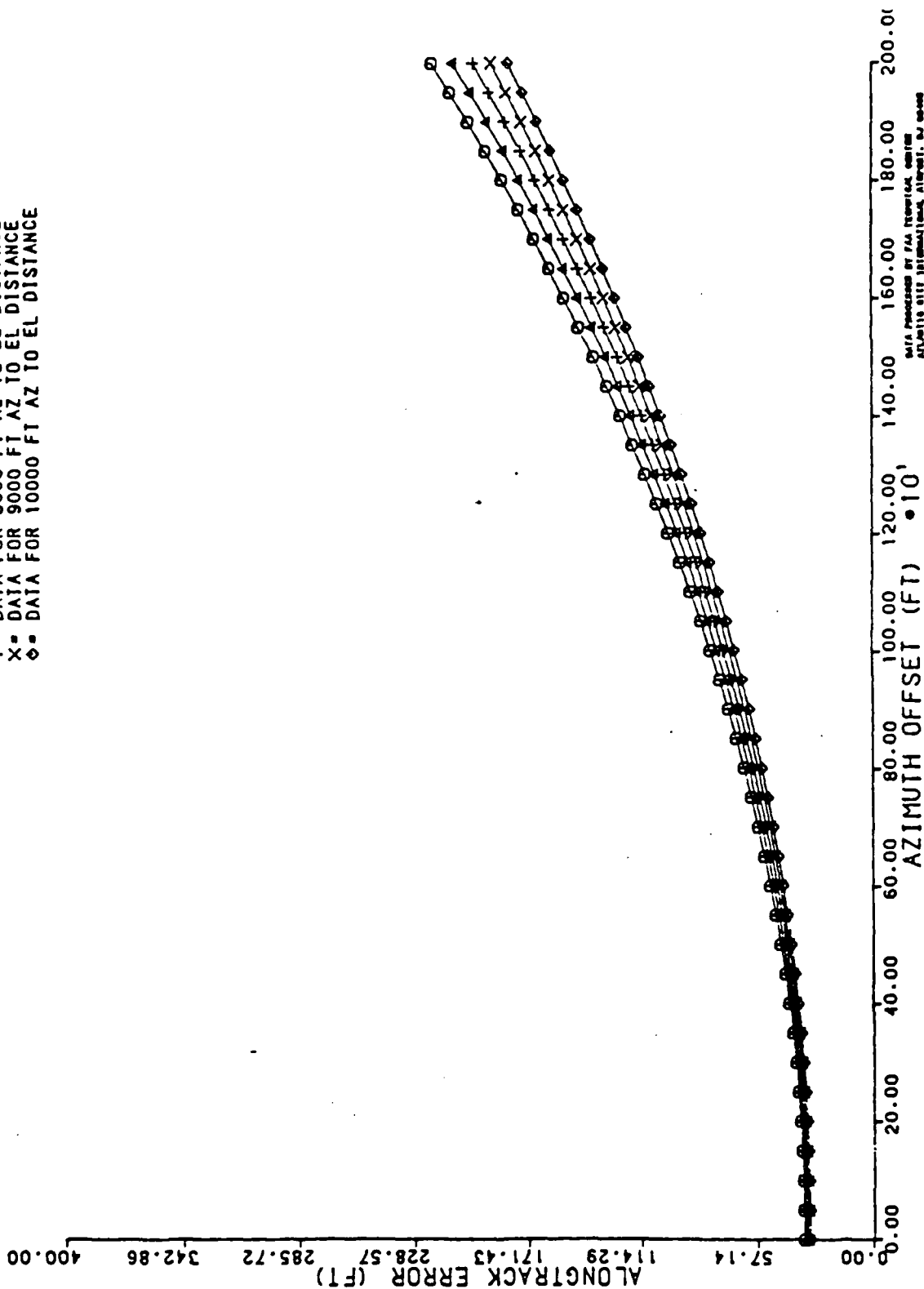


FIGURE 7. ALONG-TRACK ERROR INDUCED AT 3 DEGREE APPROACH  
ARD FOR CATEGORY III

ERRORS FROM 2D POSITION COMPUTATION  
APPROACH ANGLE: 3° 5' NMI SLANT RANGE

○= DATA FOR 6000 FT AZ TO EL DISTANCE  
△= DATA FOR 7000 FT AZ TO EL DISTANCE  
+= DATA FOR 8000 FT AZ TO EL DISTANCE  
x= DATA FOR 9000 FT AZ TO EL DISTANCE  
◇= DATA FOR 10000 FT AZ TO EL DISTANCE



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FIGURE 8. ALONG-TRACK ERROR INDUCED AT 5 NMI FROM MLS  
DATUM ON A 3 DEGREE APPROACH



ERRORS FROM 2D POSITION COMPUTATION  
APPROACH ANGLE: 6° CATEGORY I

- DATA FOR 6000 FT AZ TO EL DISTANCE
- △- DATA FOR 7000 FT AZ TO EL DISTANCE
- + - DATA FOR 8000 FT AZ TO EL DISTANCE
- x- DATA FOR 9000 FT AZ TO EL DISTANCE
- ◇- DATA FOR 10000 FT AZ TO EL DISTANCE

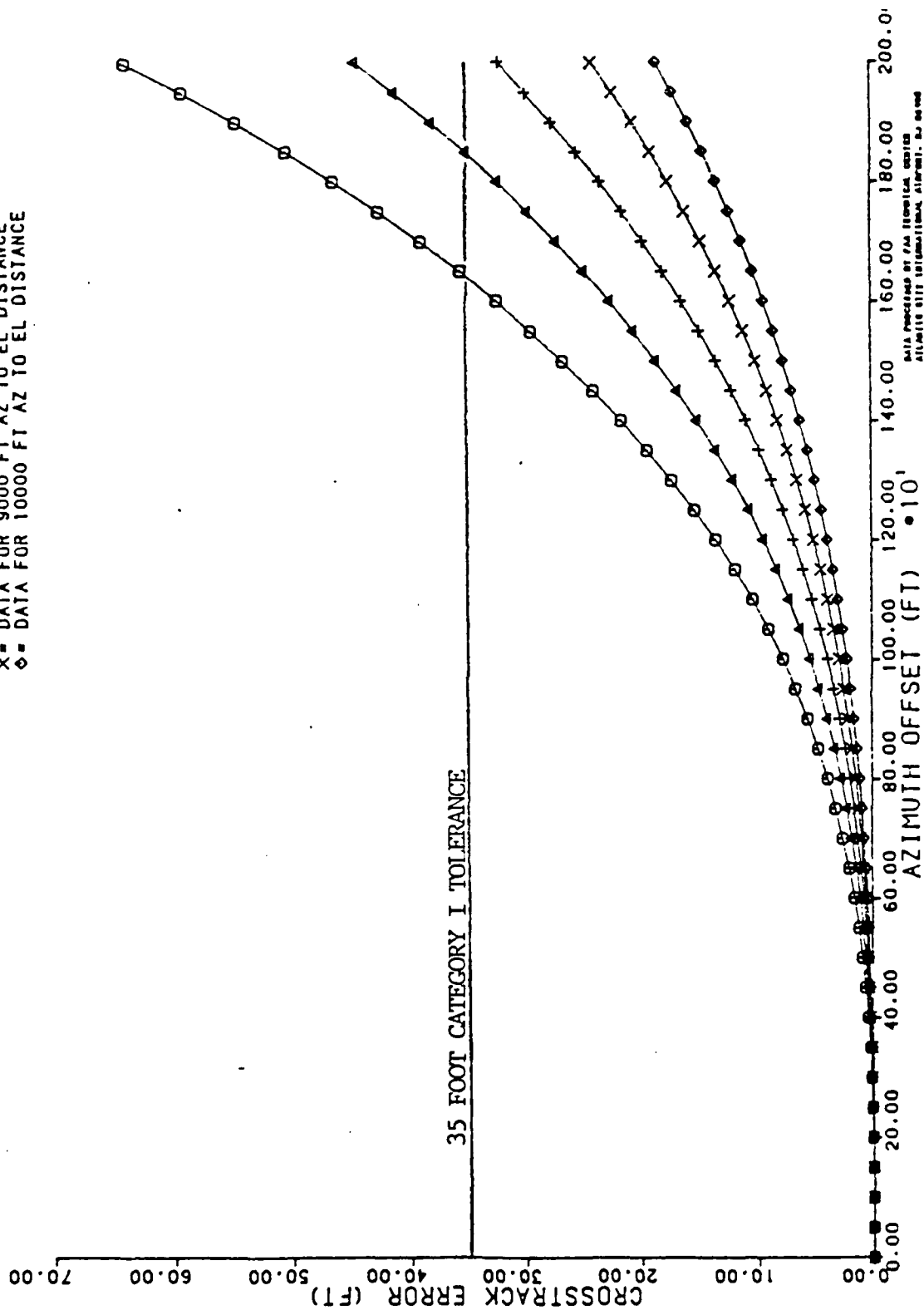


FIGURE 9. CROSSTRACK ERROR INDUCED AT 6 DEGREE APPROACH  
CATEGORY I MINIMA

ERRORS FROM 2D POSITION COMPUTATION  
APPROACH ANGLE, 6° CATEGORY II

○= DATA FOR 6000 FT AZ TO EL DISTANCE  
△= DATA FOR 7000 FT AZ TO EL DISTANCE  
+ = DATA FOR 8000 FT AZ TO EL DISTANCE  
x = DATA FOR 9000 FT AZ TO EL DISTANCE  
◇ = DATA FOR 10000 FT AZ TO EL DISTANCE

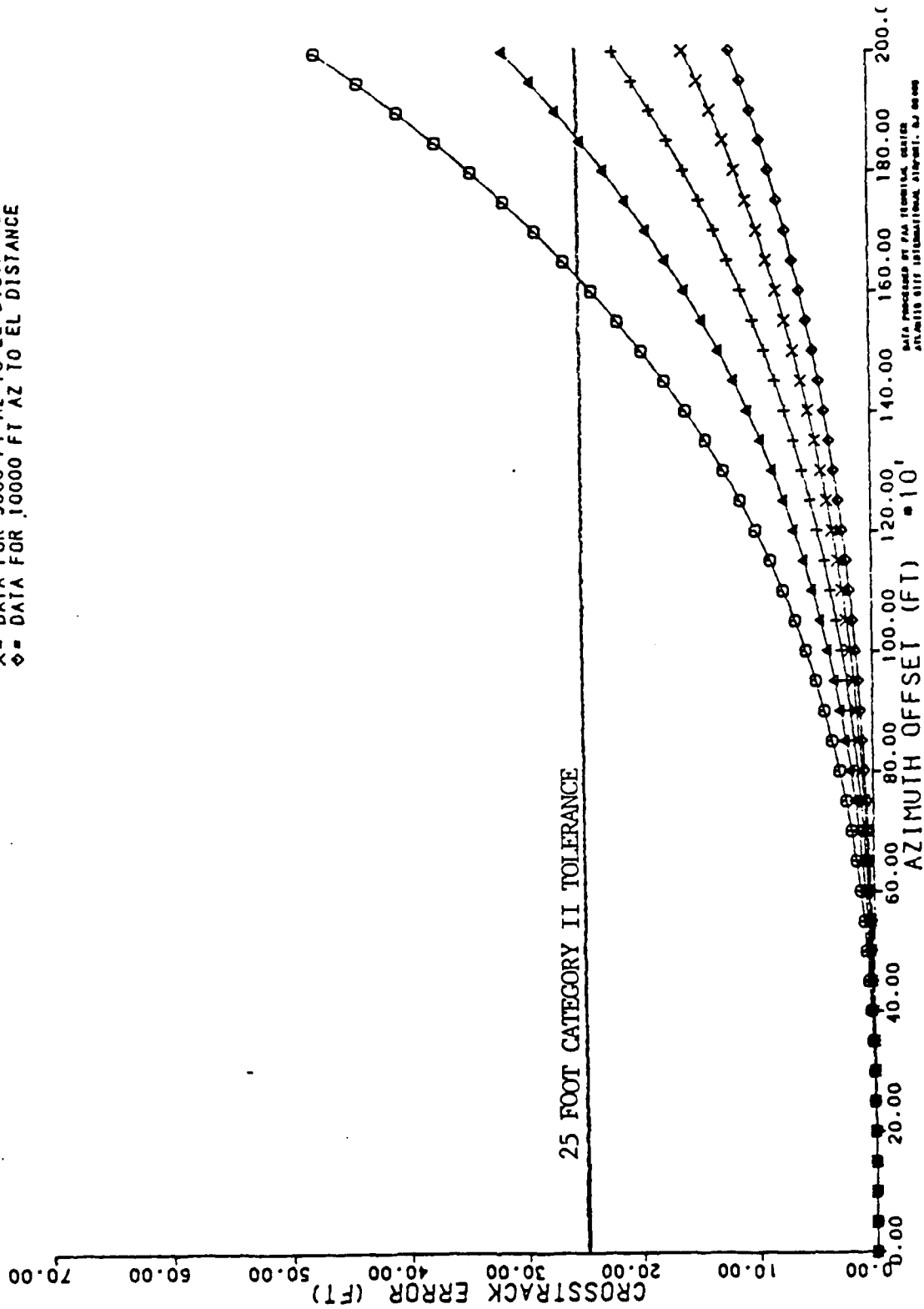


FIGURE 10. CROSSTRACK ERROR INDUCED AT 6 DEGREE APPROACH  
CATEGORY II MINIMA

ERRORS FROM 2D POSITION COMPUTATION  
APPROACH ANGLE: 6 CATEGORY III

○= DATA FOR 6000 FT AZ TO EL DISTANCE  
△= DATA FOR 7000 FT AZ TO EL DISTANCE  
+= DATA FOR 8000 FT AZ TO EL DISTANCE  
x= DATA FOR 9000 FT AZ TO EL DISTANCE  
◇= DATA FOR 10000 FT AZ TO EL DISTANCE

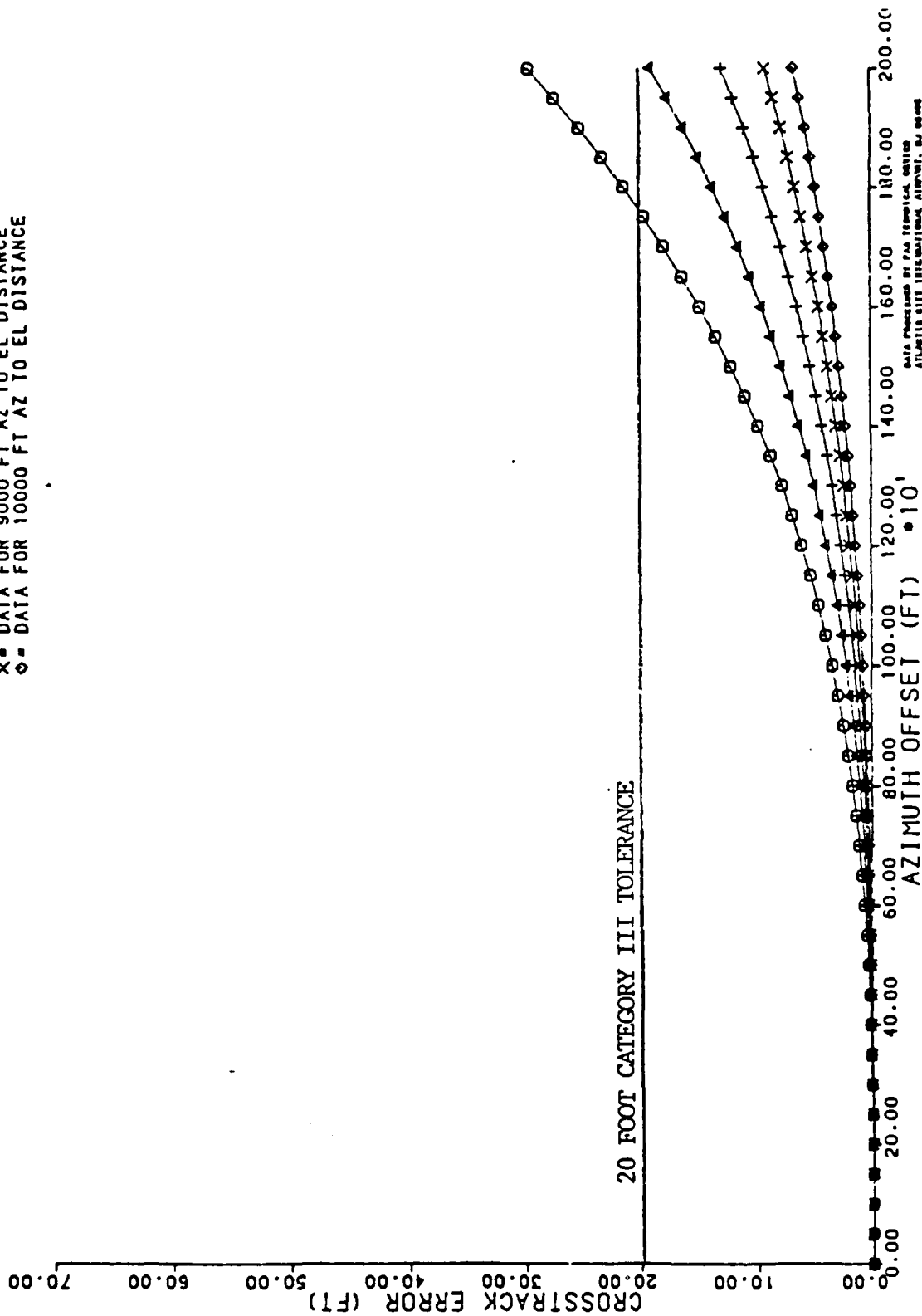


FIGURE 11. CROSSTRACK ERROR INDUCED AT 6 DEGREE APPROACH  
ARD FOR CATEGORY III

ERRORS FROM 2D POSITION COMPUTATION  
APPROACH ANGLE, 6° 5 NMI SLANT RANGE

○- DATA FOR 6000 FT AZ TO EL DISTANCE  
△- DATA FOR 7000 FT AZ TO EL DISTANCE  
+- DATA FOR 8000 FT AZ TO EL DISTANCE  
x- DATA FOR 9000 FT AZ TO EL DISTANCE  
◇- DATA FOR 10000 FT AZ TO EL DISTANCE

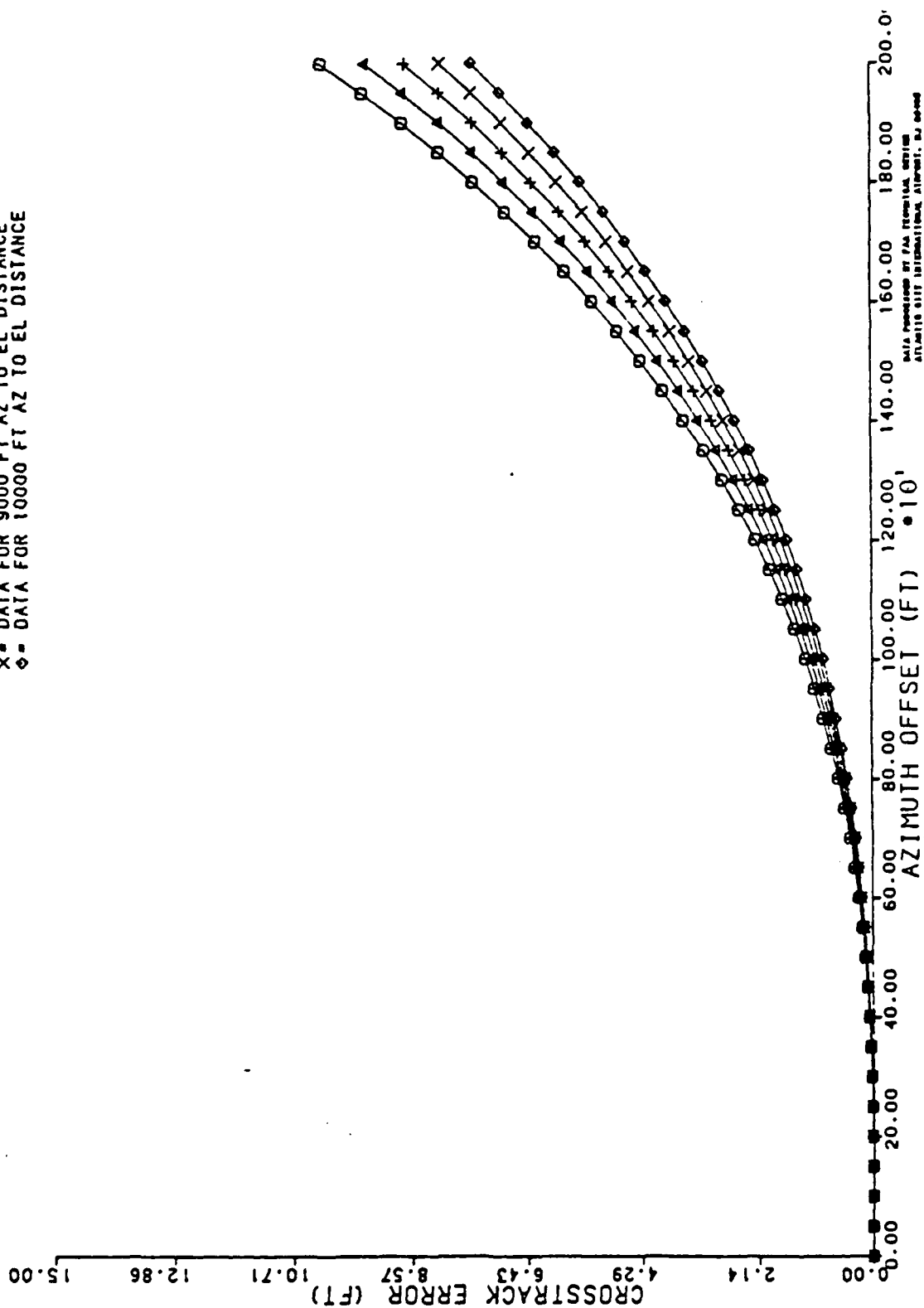


FIGURE 12. CROSSTRACK ERROR INDUCED AT 5 NMI FROM MLS  
DATUM ON A 6 DEGREE APPROACH

ERRORS FROM 2D POSITION COMPUTATION  
APPROACH ANGLE: 6 CATEGORY I

○= DATA FOR 6000 FT AZ TO EL DISTANCE  
△= DATA FOR 7000 FT AZ TO EL DISTANCE  
+= DATA FOR 8000 FT AZ TO EL DISTANCE  
x= DATA FOR 9000 FT AZ TO EL DISTANCE  
◇= DATA FOR 10000 FT AZ TO EL DISTANCE

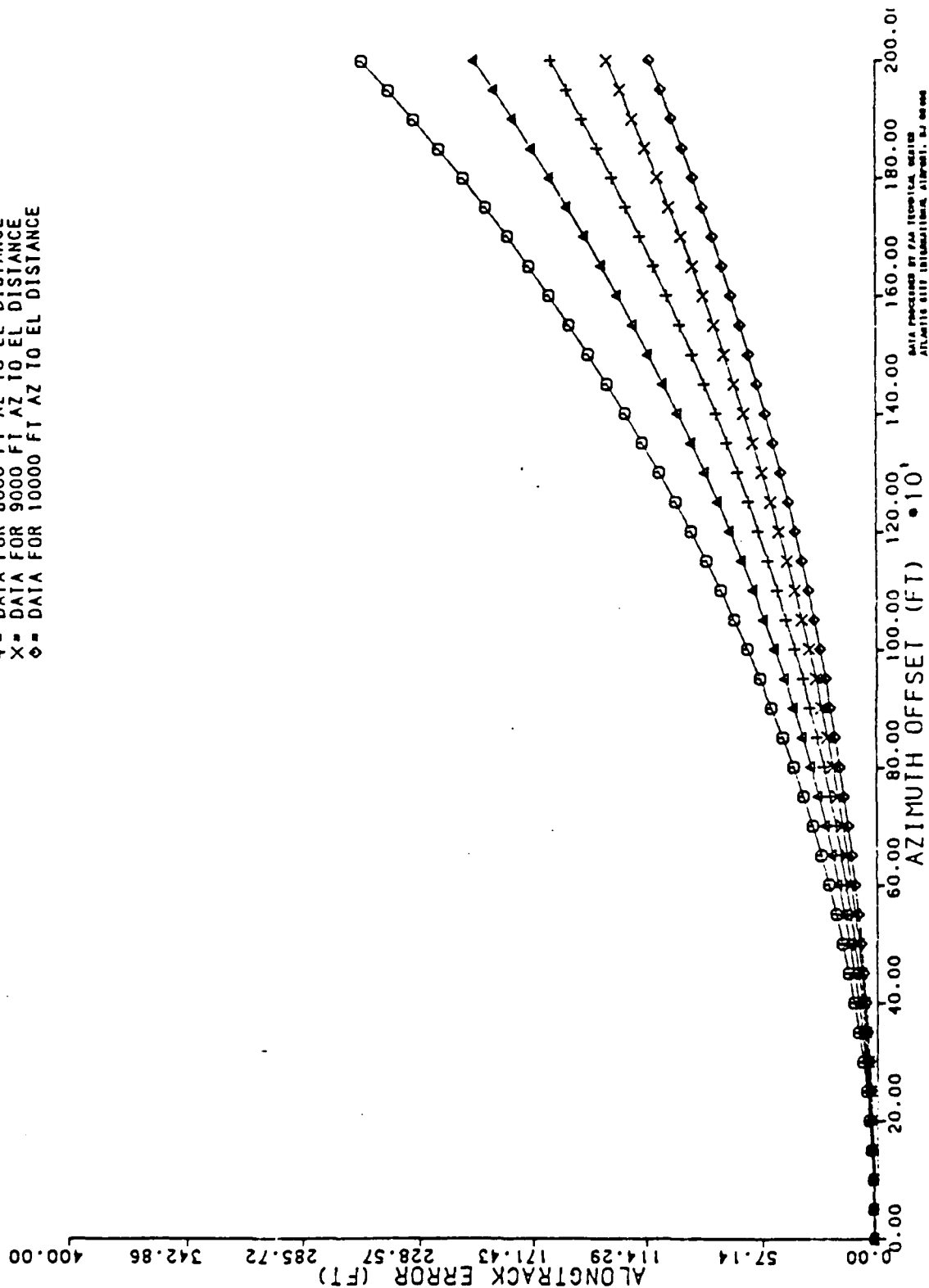


FIGURE 13. ALONG-TRACK ERROR INDUCED AT 6 DEGREE APPROACH  
CATEGORY I MINIMA

ERRORS FROM 2D POSITION COMPUTATION  
APPROACH ANGLE: 6 CATEGORY II

- DATA FOR 6000 FT AZ TO EL DISTANCE
- △ DATA FOR 7000 FT AZ TO EL DISTANCE
- + DATA FOR 8000 FT AZ TO EL DISTANCE
- x DATA FOR 9000 FT AZ TO EL DISTANCE
- ◇ DATA FOR 10000 FT AZ TO EL DISTANCE

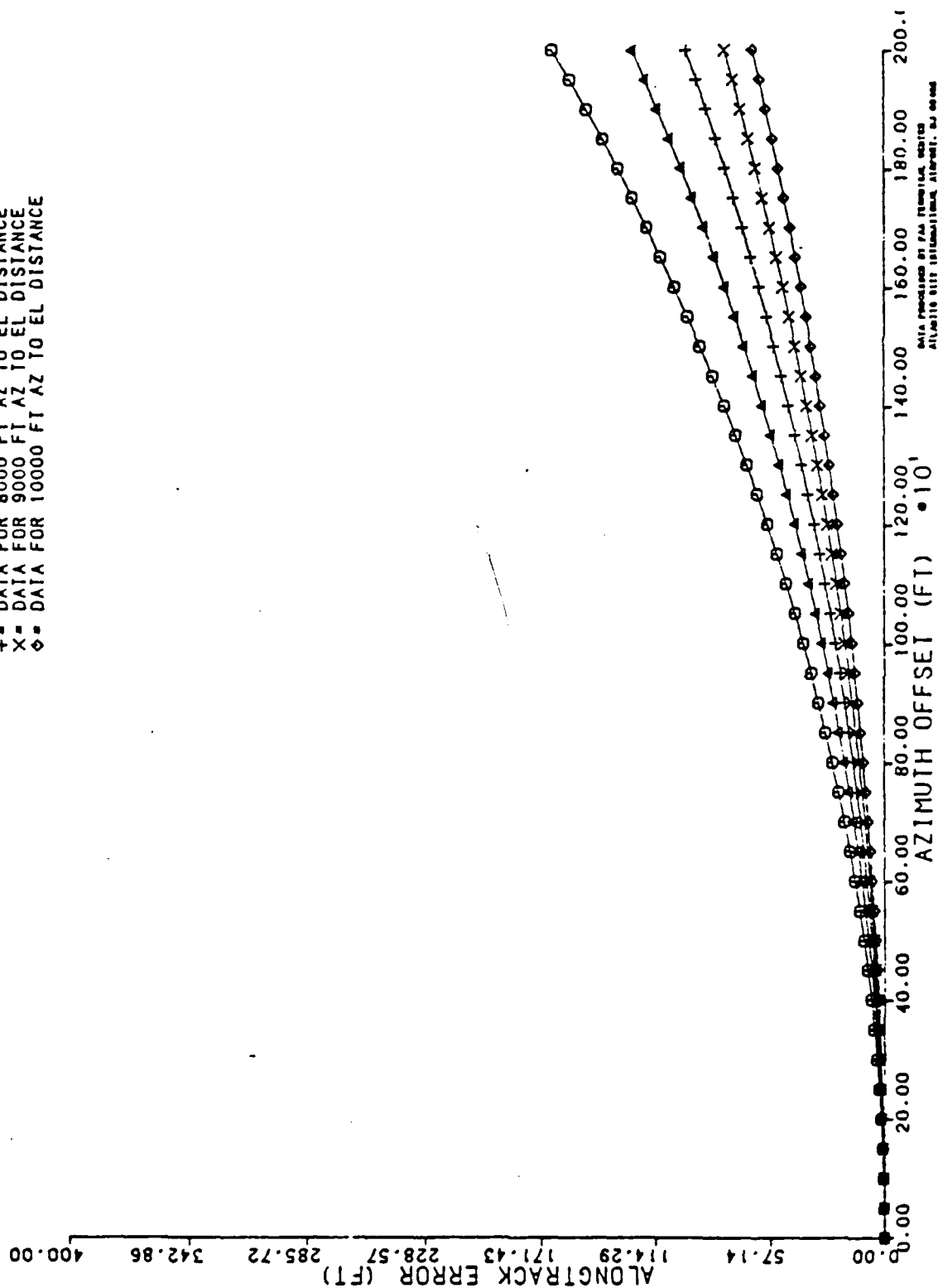


FIGURE 14. ALONG-TRACK ERROR INDUCED AT 6 DEGREE APPROACH  
CATEGORY II MINIMA

ERRORS FROM 2D POSITION COMPUTATION  
APPROACH ANGLE: 6 CATEGORY III

○= DATA FOR 6000 FT AZ TO EL DISTANCE  
△= DATA FOR 7000 FT AZ TO EL DISTANCE  
+= DATA FOR 8000 FT AZ TO EL DISTANCE  
x= DATA FOR 9000 FT AZ TO EL DISTANCE  
◇= DATA FOR 10000 FT AZ TO EL DISTANCE

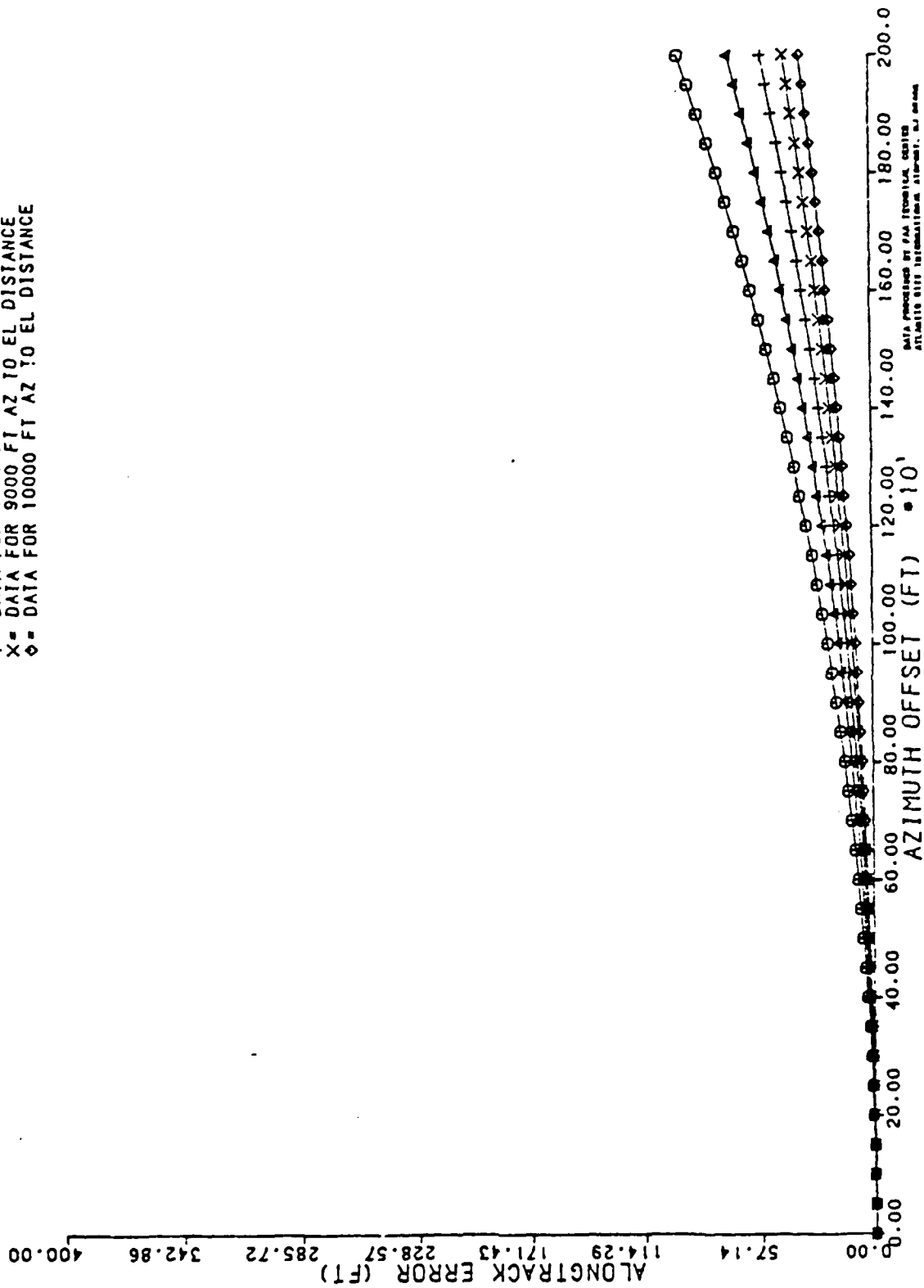


FIGURE 15. ALONG-TRACK ERROR INDUCED AT 6 DEGREE APPROACH  
ARD FOR CATEGORY III

ERRORS FROM 2D POSITION COMPUTATION  
APPROACH ANGLE: 6 5 NMI SLANT RANGE

○= DATA FOR 6000 FT AZ TO EL DISTANCE  
△= DATA FOR 7000 FT AZ TO EL DISTANCE  
+= DATA FOR 8000 FT AZ TO EL DISTANCE  
x= DATA FOR 9000 FT AZ TO EL DISTANCE  
◇= DATA FOR 10000 FT AZ TO EL DISTANCE

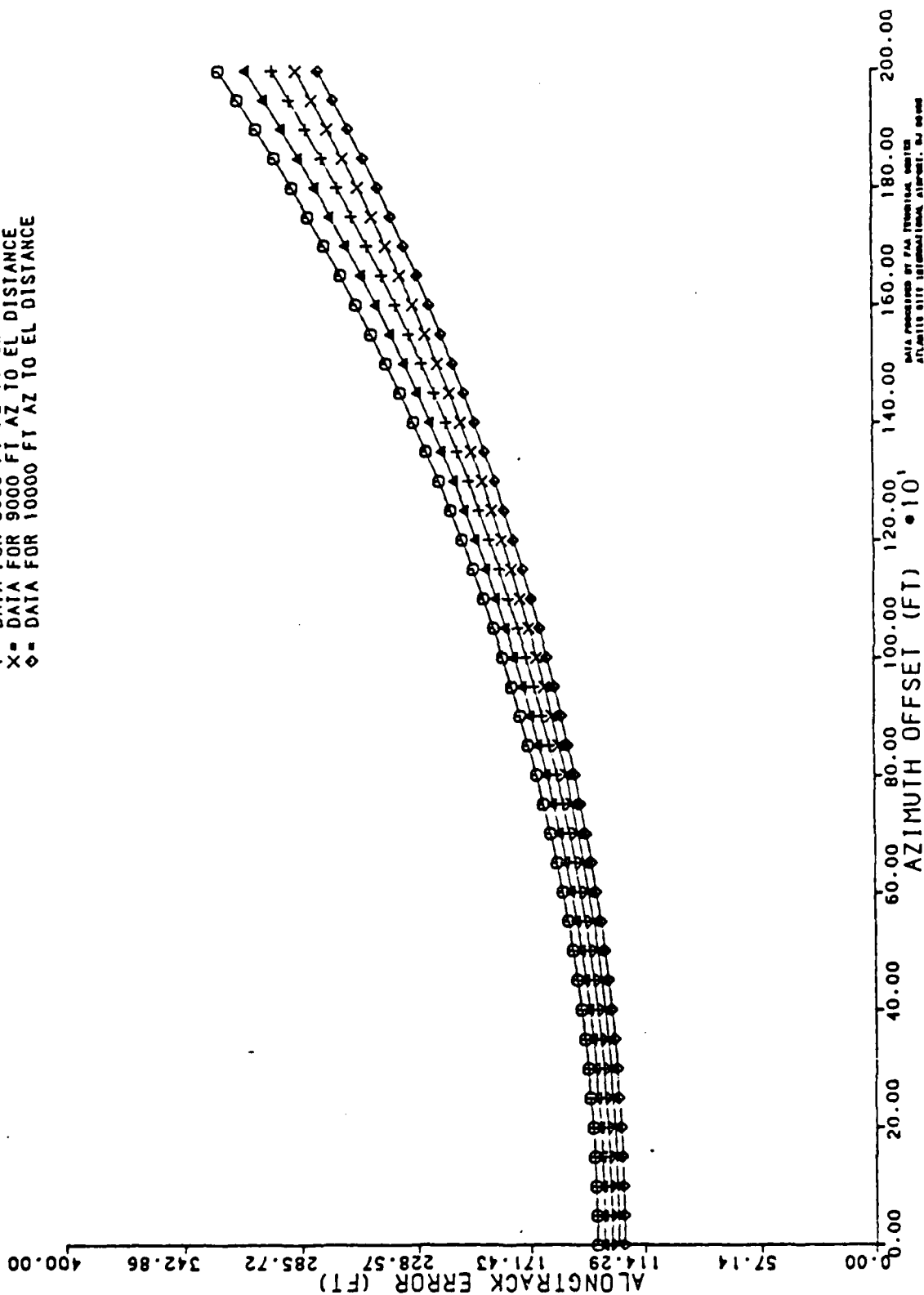


FIGURE 16. ALONG-TRACK ERROR INDUCED AT 5 NMI FROM MLS  
DATUM ON A 6 DEGREE APPROACH